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This issue contains articles on the following subjects:1.Mental Workload Assessment; 2.From the Sublime to the Meticulous: a Look at Some Approaches to Displays for Really Large Systems; 3.Stooped vs. Squat Lifting Techniques; 4.Electronic Food Kiosks

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CSERIAC GATEWAY

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CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Alexandria, VA, managed by the Armstrong Laboratory Human Engineering Division, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

Figure 1. An example of physiological data collection during a flight in a civilian aircraft using a small amplifier/recorder unit. Electrodes used to record eye blinks and eye movements can be seen. Heart rate and brainwave data were also collected. Photo courtesy of Tanya Ellifritt, Armstrong Laboratory Human Engineering Division.

Mental Workload Assessment

Glenn F. Wilson & F. Thomas Eggemeier

During the fifteen-year period since the publication of several influential works pertaining to mental workload and its assessment (e.g., Moray, 1979; Wierwille, 1979; Williges & Wierwille, 1979), significant advances have been made in development of workload assessment techniques and in refinement of guidelines for their application. Several recent reviews of mental workload assessment techniques document the latest developments in the field and should be consulted by a practitioner who is interested in application of such techniques (e.g., Eggemeier & Wilson, 1991; Hancock & Meshkati, 1988; Hart & Wickens, 1990; Lysaght et al., 1989; Moray, 1988; Wierwille & Eggemeier, 1993; Wilson & Eggemeier, 1991). A number of reviews (e.g., Gopher & Donchin, 1986; Hart & Wickens, 1990; O'Donnell & Eggemeier, 1986) include guidance about the choice of a workload mea-

Continued on page 2

surement technique for a given application, and Wierwille and Eggemeier (1993) provide recommendations for techniques to be used during test and evaluation. This article presents an overview of some currently available mental workload assessment techniques which appear suitable for use in applications environments. Three major classes of workload assessment techniques are discussed: (1) behavioral or performance-based techniques, (2) subjective assessment techniques, and (3) psychophysiological techniques. Figure 1 provides an example of psychophysiological methods used in an applied setting.

Behavioral Measurement Techniques

Behavioral or performance-based workload assessment procedures reflect the ability of the operator to perform tasks in the simulated or operational environment. One such procedure is the so-called *primary task measurement*, which assesses the ability of the operator to perform the system function which is the subject of the workload analysis. For example, evaluation of a driver's ability to maintain control of an automobile under adverse weather conditions represents an example of primary task measurement of the workload imposed by such conditions. Although primary task measures should be employed to detect breakdowns in operator performance which can be attributed to high workload, such measures are not always considered sensitive to variations in load under low-to-moderate workload conditions (e.g., Eggemeier & Wilson, 1991; Hart & Wickens, 1990; O'Donnell & Eggemeier, 1986). Therefore, primary task measures should normally be supplemented through use of other workload assessment techniques. In many operational situations, it is difficult to acquire performance data because most systems are not equipped to provide information about operator performance.

In addition to primary task measures, *secondary task measurement* can also be considered for assessment of operator workload in simulation or operational environments. Secondary task methodology involves the addition of a second task (e.g., mental mathematics, memory search, tracking) to the operator's primary task. The measure of workload is typically derived from the ability of the operator to perform the secondary task concurrently with the primary task. In the example used above, the capability of the driver to perform a short-term memory task while driving under adverse weather conditions represents an example of the use of secondary task methodology to evaluate the workload imposed by the weather conditions. Presumably, the capability to perform the short-term memory task would be reduced under adverse weather conditions when compared to (a) performance under ideal weather conditions, and (b) a control condition in which only the memory task was performed. Secondary task measures can cause degradations in ongoing primary task performance (e.g., Eggemeier & Wilson, 1991; Hart & Wickens, 1990) and should therefore be applied with some caution, particularly in operational environments. If this procedure is used, it is desirable that the secondary task demands be similar to those required by the primary task to gain maximum sensitivity. Hart and Wickens (1990) and Eggemeier and Wilson (1991) discuss matching the information-processing demands of the secondary task with those of the primary task. A number of reviews (e.g., Hart & Wickens, 1990; Eggemeier & Wilson, 1991; Lysaght et al., 1989) discuss secondary tasks which have been frequently employed. The so-called *embedded secondary task* involves using actual components of required performance within the system which is under evaluation. For example, the capability of the operator to monitor panel instruments or to process information from a radio broadcast might be used to evaluate the workload of the primary driving task.

Subjective Assessment Techniques

A class of assessment techniques which is generally applicable to simulation or operational environments and which has been the focus of considerable development in recent years is the subjective measurement approach. Although actual data collection procedures can vary with both the subjective technique used and its application, this approach to workload assessment generally involves completion of a rating scale by the operator subsequent to task performance. This method characterizes the subjective mental workload associated with the system or task under evaluation. The instrumentation requirements associated with gathering estimates of workload and the possibility of disruption of ongoing operator performance are usually minimized with the use of such measures.

A number of subjective assessment techniques developed within the past fifteen years should be considered by the practitioner for application. These techniques are shown in Table 1. Several recent reviews (e.g., Eggemeier & Wilson, 1991; Lysaght et al., 1989; Wierwille & Eggemeier, 1993) discuss available information on comparisons of some of these techniques and should be consulted for additional information related to the choice of a particular technique. A number of cautions in the application and interpretation of subjective measures (e.g., Eggemeier & Wilson, 1991; Hendy et al., 1993; Nygren, 1991; O'Donnell & Eggemeier, 1986) should also be considered in the application of such measures. Some of these considerations include the utility of uni- vs. multi-dimensional scales and scale development for individual operators. Subjective measures

Table 1
Subjective Assessment Techniques

- Subjective Workload Assessment Technique (SWAT) (Reid & Nygren, 1988)
- NASA Task Load Index (TLX) (Hart & Staveland, 1988)
- Modified Cooper-Harper (MCH) Technique (Wierwille & Casali, 1983)
- Bedford Scale (Roscoe, 1987)
- Subjective Workload Dominance Technique (SWORD) (Vidulich, 1989)

may be susceptible to operator bias and memory difficulties.

Psychophysiological Techniques

Psychophysiological measures have been used for a number of years to evaluate operator mental workload. The measures typically used include heart rate, eye blinks, respiration, brain waves, and analysis of body fluids. Their measurement usually does not intrude into the operator's primary task and they provide continuous information from the operator. Psychophysiological methods have been used to address workload issues in laboratory, simulator, and "real-world" environments (Kramer, 1991; Wierwille & Eggemeier, 1993; Wilson & Eggemeier, 1991). Recent advances in hardware and software have made physiological data easier to acquire and analyze in each of these environments.

Current physiological equipment has been reduced in size so that a full set of amplifiers and recording media can be easily worn by ambulatory operators while performing their normal duties. This includes heart rate, eye blinks, respiration, and brain waves. Portable, multi-channel systems are now available that permit the simultaneous recording of at least 32 brain-wave channels, heart rate, eye blinks, and respiration. In addition to the typical off-line data reduction procedures, systems are being developed that provide on-line data reduction with artifact correction. One system is designed to provide on-line classification of subject condition so that estimates of workload, fatigue, and other operator states can be provided to the operator and/or the system during the task. These systems also preserve the data so that in-depth and/or different analyses may be accomplished later.

Special issues of professional journals have included psychophysiological measures of mental workload in applied settings. Recent examples include *Human Factors*, April 1987; "Cognitive Psychophysiology," *29* (2), 127-237; *Biological Psychology*, November 1992, "Cardiorespiratory Measures and Their Role in Studies of Performance," *34* (2-3), 91-290; *Ergonomics*, September 1993, "Psychophysiological Measures in Transport Operations," *36* (9), 989-1140; *Biological Psychology*, In press, "EEG in Basic and Applied Settings."

With regard to specific measures, heart rate can provide an estimate of the overall demands of the situation, eye blinks are a good measure of visual demands, and EEG-based measures can tap into the mental demands of a given situation. Psychophysiological as well as performance and subjective measures can be used to derive a composite workload estimate that takes advantage of the sensitivities of the several measures.

Recommendations

Since many current systems are quite complex, it seems advisable to use a combination of workload measurement techniques to evaluate these systems. These systems place demands on the operators that are high and involve several aspects of the operator's mental abilities. To understand these situations it is advisable to gather as much data as possible. However, a thoughtful approach must be used to take advantage of the information value of each of the measures, since a shotgun approach of using every available measure can lead to confusing and contradictory results. Even when appropriate methods are used, there will no doubt be areas of overlap and it may be the areas of disagreement between measures that can provide the most information about operator workload. ●

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COTR Speaks

Reuben L. Hann

In this issue of *Gateway*, Dr. Tom Eggemeier (Department of Psychology, University of Dayton) and Dr. Glenn Wilson (Armstrong Laboratory Human Engineering Division) present a survey of the various techniques for measuring the amount of *mental workload* imposed upon the user of a system. Their review groups the various approaches into behavioral, subjective, and physiological techniques.

Dr. Neville Moray (University of Illinois) was the fifth speaker in the 1993 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. Ken Klauer, CSERIAC Human Factors Analyst, presents a synopsis of his lecture, which is followed by excerpts from a conversation I had with Neville during his visit.

Have you ever considered the strain on your back *before* lifting a heavy object? Or like most people, do you consider it only *after* the damage is done? Ed Eveland, a doctoral student in the Biomedical Sciences Program at Wright State University, looks at two different lifting techniques, stooped and squat, as well as some of the issues involved in the current National Institute for Occupational Safety and Health (NIOSH) guidelines for lifting.

In nearly 6 years of existence, CSERIAC has provided guidance to many individuals and organizations for the proper application of human factors in their designs. A recent example of how CSERIAC provided such assistance was with an electronic food kiosk being planned by AT&T. CSERIAC Analyst Ken Klauer performed a *Search & Summary* which defined some of the parameters to be considered in such a design. Ken's article describes a bit of the process involved in helping AT&T, and discusses the CSERIAC Search & Summary service in general.

In an earlier issue of *Gateway* (Vol. III, No. 3, 1992), Dr. Dave Post (Armstrong Laboratory Human Engineering Division) wrote a brief article on a newly released book edited by him and Heino Widdel (Forschunginstitut für Anthropotechnik), *Color in Electronic Displays*. In this issue, we publish a review of this book that first appeared in *Color Research and Application* (Vol. 19, No. 2, April 1994).

We at CSERIAC are always interested in your inputs. If you have an idea for an article in *Gateway*, or want to submit one of your own, please don't hesitate to contact our Editor, Jeff Landis. In any case, even if you don't have ideas for articles, we still want your feedback. We have received many compliments about this publication; with your help, we will strive to make it even better. ●

Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Manager for the CSERIAC Program.

Announcements

Human Factors and Ergonomics Society Placement Service

The Human Factors and Ergonomics Society (HFES) offers an opportunity for employers seeking human factors/ergonomics expertise to tap into the tremendous knowledge base and range of experience of HFES members and other professionals in related fields.

Candidates are computer-matched with available jobs on the following criteria:

Highest degree held	**Areas of interest**
Major field of study	**Employment sector**
Years of experience	**Geographical Area**
Salary	**Type of position**

The HFES Placement Service can help in filling full-time, part-time, or consulting positions. Both members and nonmembers may use the service for renewable four-month terms. Anonymity will be maintained if requested by the user.

Call HFES at (310) 394-1811 or fax (310) 394-2410 to obtain rates and application forms.

BCPE Certification Examination Scheduled

The Board of Certification in Professional Ergonomics (BCPE) has scheduled the first written examination to be administered in partial fulfillment of its certification criteria for designation as a Certified Professional Ergonomist (CPE) or Certified Human Factors Professional (CHFP). The examination will be given Saturday, October 29, 1994 at the Stouffer Hotel, Nashville, TN, after the conclusion of the 38th Annual Meeting of the Human Factors and Ergonomics Society (October 24-28, 1994).

Potential candidates for certification are invited to request application materials by sending a check for $10 to:

BCPE
P.O. Box 2811
Bellingham, WA 98227-2811

The application processing fee (including testing) is $190 payable prior to September 2, 1994. Applications received after this date may be rejected for the first test administration due to limited space availability. (If space is available, a $50 surcharge will be required for "special handling" after September 2, 1994 for the October 29 sitting.)

Practitioners having an MA/MS (or equivalent educational background in the life sciences, engineering sciences, and behavioral sciences to comprise a professional level of ergonomics education), four years of full-time professional practice as an ergonomist/human factors specialist with emphasis on ergonomic design involvement, and the submission of a work product demonstrating the application of ergonomics to a product, process, or work environment will be qualified to take the examination. A passing score will then complete the requirements to be issued a certificate.

The BCPE has awarded the CPE and CHFP designations since 1992. The Board consists of nine Directors who have been instrumental in shaping the profession over the past 40 years. In 1990, they established the BCPE as a non-profit corporation for purposes of enhancing the education, skills, and practices of practitioners in the profession as a distinct discipline. Although functioning as an independent organization, the BCPE maintains close coordination with those scientific societies and trade associations that have similar interests (e.g., Human Factors and Ergonomics Society, and International Ergonomics Association).

GATEWAY

Visit the CSERIAC Display at These Meetings	SAE Aerotech '94	National Safety Council Congress & Exposition	Annual Meeting of the Human Factors & Ergonomics Society
	Los Angeles, CA,	San Diego, CA	Nashville, TN
	October 3-6, 1994	October 23-28, 1994	October 24-28, 1994

Calendar

October 3-6, 1994
Los Angeles, CA, USA
Aerotech '94, "Affordable Aerospace: Shaping the Future Through Technology Integration." Sponsored by SAE. Contact SAE Communication & Meetings, Promotion Division, 400 Commonwealth Dr., Warrendale, PA 15096; (412) 776-4841, fax (412) 776-5760.

October 11-16, 1994
Montgomery, AL, USA
Quality Air Force Symposium '94, "Shaping the Future." Sponsored by the U.S. Air Force Quality Institute. Contact Maj. Jim Harvard, AFQI/RS, Bldg. 1400A, 825 Chennault Circle, Maxwell AFB, AL 36112-6425; (205) 953-3964, DSN 493-3964; or Gina Thomas, the CSERIAC Conference Coordinator, (513) 255-4842, DSN 785-4842, fax (513) 255-4823; email: CSERIAC @Falcon.AAMRL.WPAFB.AF.MIL. For reservations contact SatoTravel, (800) 347-6338, fax (713) 435-7946. *Conference is limited to 2,000 attendees.*

October 22-26, 1994
Research Triangle Park, NC, USA
Computer-Supported Cooperative Work '94. Contact John B. Smith, Department of Computer Science, University of North Carolina, Chapel Hill, NC 27599-3175; (919) 962-1792.

October 23-28, 1994
San Diego, CA, USA
National Safety Council Congress & Exposition. Contact National Safety Council, 1121 Spring Lake Dr., Itasca, IL 60143-3201; (708) 285-1121, fax (708) 285-1315.

October 24-28, 1994
Nashville, TN, USA
38th Annual Meeting of the Human Factors and Ergonomics Society, "People & Technology in Harmony." Cohosted by the Smoky Mountain and Tennessee Valley Chapters. Contact HFES, P.O. Box 1369, Santa Monica, CA 90406-1369; (310) 394-1811, fax (310) 394-2410.

October 31-November 3, 1994
Orlando, FL, USA
33rd Meeting of the Department of Defense Human Factors Engineering Technical Advisory Group. Contact Dr. Joe McDaniel, AL/CFHD, 2255 H Street, Wright-Patterson AFB, OH 45433-7022; (513) 255-2558, fax (513) 255-9198.

October 31-November 3, 1994
Arlington, VA, USA
Defense Technical Information Center Annual Users Training Conference, "Today's Information Meeting Tomorrow's Challenges." Located at the Stouffer Concourse Hotel. Contact Patti Miller, Defense Technical Information Center, Cameron Station, Bldg. 5, Alexandria, VA 22304-6729; (703) 274-3848, DSN 284-3848, fax (703) 274-6708.

November 8-9, 1994
Albuquerque, NM, USA
9th Annual FAA Meeting on Human Factors in Aircraft Maintenance and Inspection. Contact Suzanne Morgan, Galaxy Scientific Corporation, 2310 Parklake Dr., Suite 325, Atlanta, GA 30345; (404) 491-1100, fax (404) 491-0739.

December 13-16, 1994
Orlando, FL, USA
The Department of Defense (DoD) Liveware/Human System Integration Tool Workshop has been postponed pending the results of the DoD Process Action Team on Acquisition Oversight and Review that was established by the Secretary of Defense on September 6, 1994.

April 4-6, 1995
Canterbury, Kent, UK
The Ergonomics Society Annual Conference 1995. Contact the Conference Manager, The Ergonomics Society, Devonshire House, Devonshire Square, Loughborough, Leicestershire LE11 3DW, UK; telephone/fax +44 (509) 234904. *Abstracts due September 23, 1994.*

April 24-28, 1995
Dayton, OH, USA
6th Annual Aerospace Atlantic Conference & Exposition, "Partnering for a Lean Aerospace Environment." Sponsored by SAE. For papers, contact Ms. Karen Mong, SAE Aerospace Atlantic '95, 400 Commonwealth Dr., Warrendale, PA 15096; fax (412) 776-1830. For exhibits, contact Mr. Patrick Cantini, SAE Exhibits Division at (412) 772-7174. *Abstracts due October 7, 1994.*

September 24-28, 1995
Montréal, Québec, Canada
2nd International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS 95. Organized by the Institut de recherche en santé et en sécurité du travail du Québec (IRSST). Contact IRSST, 505, Boulevarde de Maisonneuve Ouest, Montréal, Québec, Canada, H3A 3C2; (514) 288-1551, fax (514) 288-7636. *Abstracts due March 15, 1995.*

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022

Armstrong Laboratory Human Engineering Division Colloquium Series

From the Sublime to the Meticulous: A Look at Some Approaches to Displays for Really Large Systems

Neville Moray
Synopsis by Ken Klauer

Editor's Note: Following is a synopsis of a presentation by Dr. Neville Moray, University of Illinois, as the fifth speaker in the 1993 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. This synopsis was prepared by Ken Klauer, Human Factors Analyst, CSERIAC Program Office. JAL

Dr. Moray's presentation included displays employed in different operational contexts to illustrate several important aspects of interface design for large-scale systems. To begin, Dr. Moray proposed that the design of displays for large systems is somewhat different from those used in smaller systems such as aircraft. The dynamics of aircraft and the displayed information mapped to critical variables are relatively well understood. In contrast, the factorial complexity of large-scale systems such as nuclear generating stations prevents designers from conceiving all possible system states. Because all possible system states can not be enumerated, it is difficult to predict the types of displayed information and formats that will be needed.

Large-scale system interfaces also invite consideration of the possible limitations of direct perception displays. The design of direct perception displays is based on the premise that the higher-order invariants present in a system should be mapped to optical invariants at the display interface. Displays designed in this manner minimize the cognitive transformations required to visualize the interactions between variables in a system. As Dr. Moray commented, "The soul of the machine is laid bare to the operator." However, Dr. Moray argues that the complexity of some systems may limit the advantages of direct perception displays. The number of interdependent variables needed to graphically describe the higher-order invariant(s) in a large system cannot be mapped to a single direct perception display. Multiple direct perception displays associated with various subsystems would be required to maintain complete awareness of the system. A suite of direct perception displays may be an improvement over several dozen discrete data displays, but the operator must still deduce the state of the system across multiple displays.

The first system considered was a hypothetical climate control system for a high-rise building. These systems may consist of upwards of 80,000 sensed points throughout a building. This design exercise is also an example of an application so complex that the principles of direct perception may fail to make the system transparent to the operator. While Dr. Moray concedes that the physics of heat transfer are simple — the interactions of the various microclimates which must exist from room to room in a large building are much more complex. The simple act of opening a window may dramatically alter the dynamics of the system. The internal climate of the building is also subject to external perturbations from unequal solar radiation and prevailing wind currents.

The climate control interface envisioned by Dr. Moray consisted of a color-coded outline of the target building to support a rapid assessment of the internal climate. Temperatures within each room are represented by colors from red (hot) to blue (cold) as appropriate. Within this high-level representation, each floor plan can be brought up on a separate display page, enabling the operator to examine each room individually by simply "pointing and clicking" with a mouse (see Fig. 1). Further, the operator can examine each component of the system within each room (fans, thermostats, etc.). This interface design also features a database of system profiles associated with anomalous scenarios the operator can use as a case-based diagnostic aid if problems arise. The system profiles include variables such as temperature, humidity, and airflow volume. From this database, an operator can match the current profile with anomalous profiles that have appeared in the past as an aid to generating diagnostic hypotheses.

In this example, direct perception principles are adequate to draw the operator's attention to system anomalies, but the final diagnosis can only be supported by a relatively information-intensive display of individual subsystems and components. The large number of variables associated with these systems do not easily map to a single direct perception display.

Nuclear power plant steam generation subsystems are also complex, but unlike the large-scale climate control systems, they can be adequately de-

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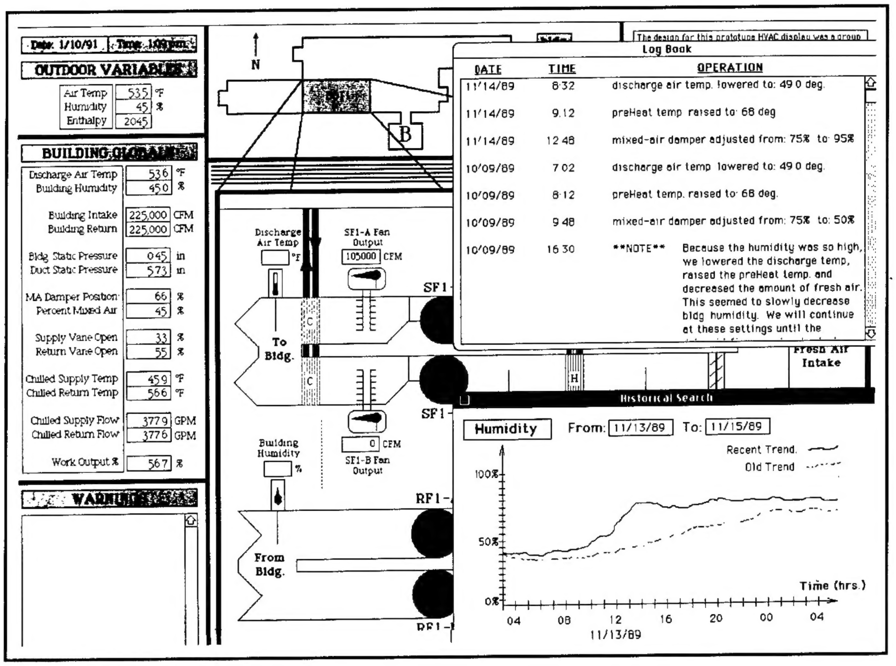

Figure 1. Moray's conceptualized climate-control interface for a large building.

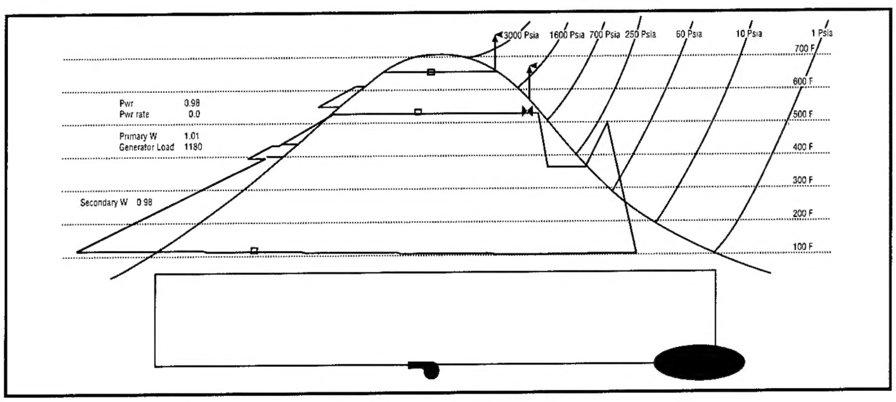

Figure 2. A Rankine Cycle display (Moray et al., 1992).

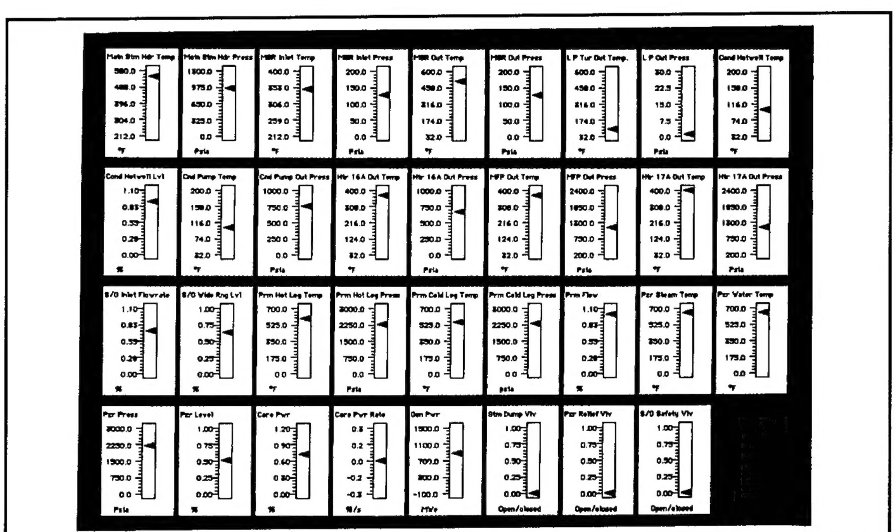

Figure 3. An analog display (Moray et al., 1992).

scribed by relatively few variables (~30-35). It is possible to map these variables to a single direct perception display to make the dynamics of steam generation transparent to the operator. Central to the understanding of steam generation is the *Rankine Cycle*, a concept by which both engineers and operators visualize the system. The system variables involved are easily mapped to a graphic representation of the Rankine Cycle (Fig. 2) as an alternative to rows of analog displays (Fig. 3). Upon viewing this display, operators should be able to rapidly assess the steam generation system. Dr. Moray noted that malfunctioning sensors in this system are particularly difficult to diagnose with analog displays, but easily indicated by the Rankine Cycle display. This condition is dramatically illustrated by the shaded line in Figure 4 as compared to the same condition in Figure 5. Equally important, sensor status is highly salient in both normal (Fig. 2) and abnormal system representations utilizing the Rankine display concept (Fig. 4).

To test the hypothesis that this direct perception representation of the Rankine Cycle can improve operator performance, Dr. Moray and his colleagues (Moray, Jones, Rasmussen, Lee, Vincente Brock, & Djemil, 1993) presented both the traditional analog displays (Fig. 3) and the direct perception Rankine display (Fig. 2) to a group of 42 undergraduates who had taken at least one course in thermodynamics, 42 graduate students in thermodynamics or nuclear engineering, and 42 professional nuclear power plant operators. Each subject employed one of the displays to view a series of nine fault scenarios for six minutes each. Immediately after each scenario, subjects were probed for one of three types of information:

1. If there had been a disturbance, what was it (diagnosis)?
2. What was general state of the plant (qualitative recall)?
3. What was the value of specific parameter(s) during the scenario (quantitative recall)?

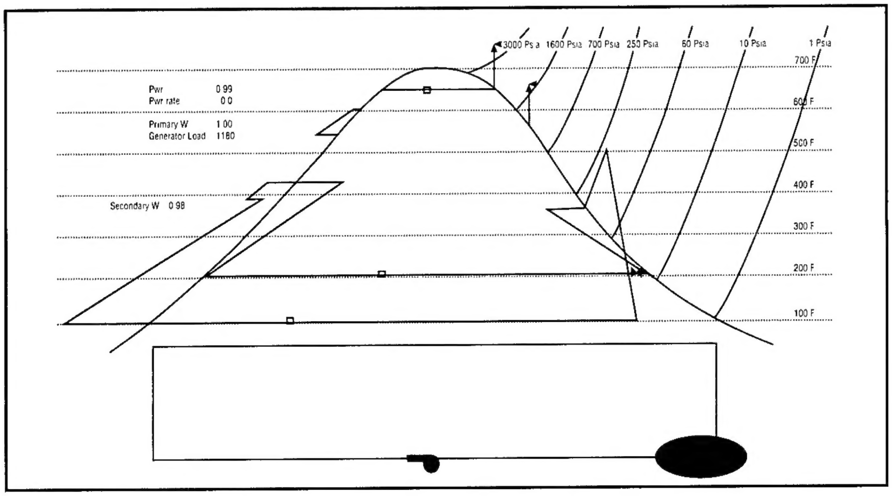

Figure 4. A Rankine Cycle display depicting a failed sensor (Moray et al., 1992).

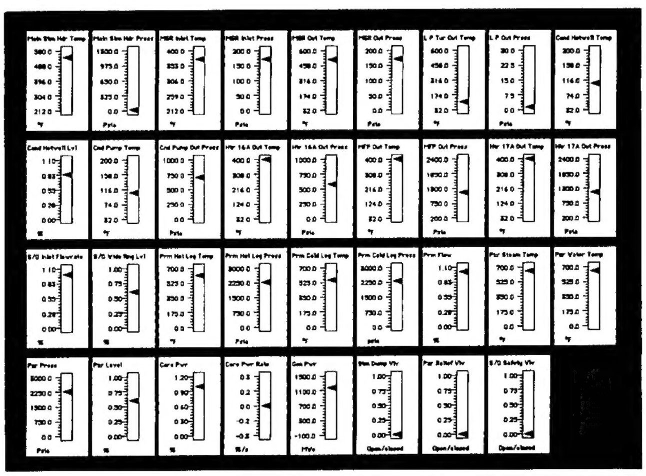

Figure 5. An analog display depicting a failed sensor (Moray et al., 1992).

Over all subject groups, the Rankine display did not improve subjects' recall of specific data values or system states. However, diagnostic performance was significantly better with the direct-perception Rankine display, even when confronted with a failed or miscalibrated sensor. Subjects viewing the Rankine display made fewer mistakes in the identification of anomalous system states than those viewing traditional analog displays.

The final system was that of a "sail-by-wire" engine room console being developed for a large, twin-engine ocean vessel. In this system, the engine operator is seated at a large wrap-around console with three CRT displays. One CRT is located in the middle, directly ahead of the operator; a port screen is located to the left, and a starboard screen to the right. Underneath each screen is a dedicated keyboard; the keyboard under the middle screen is dedicated to general system functions, while the keyboards under the port and starboard screens control the port and starboard engines respectively.

Operators may place any representation of the propulsion system on any screen and "lock" it in place. If the operator does not lock the display page in place, the system will automatically overwrite the oldest screen display. During simulator trials, operators would commonly place a high-level overview of the propulsion system on the middle screen and lock it in place. Representations of the port and starboard engines would then be placed on the left- and right-hand screens respectively. However, the left- and right-hand screens were not commonly locked on their respective screens because operators would often be required to toggle between different levels of either powerplant when emergencies arose. In this prototype system, there was nothing to prevent the operator from viewing a specific engine representation (albeit different levels of detail) on both the left- and right-hand display space. Dr. Moray and his colleagues predicted that sometime during the life-span of this system, errors would result from violations of stimulus-response stereotypes made possible by the flexibility of computer-driven displays.

Dr. Moray's prediction was realized during the first day of simulator trials, when an individual engaged in a simulation was presented with a fault in the starboard engine. Specifically, the transfer gearbox connecting the turbine output to the propeller "went red," indicating a serious condition. The operator responded by bringing up a detailed representation of the gearbox on the port screen. After analyzing the display for a moment, the operator frantically issued commands to shut down the starboard engine via the port keyboard! After about a minute, the perplexed operator turned to the experimenter and exclaimed that the simulation surely must have malfunctioned, because he could not shut down the starboard engine as he had been trained. Had this not been a simulation, this error would have caused the ship to swing hard to port, possibly damaging thousands of dollars of cargo and equipment. Dr. Moray warned that the flexibility of computerized display consoles may bring about a new typology of human errors that are understood perfectly well in retrospect, but are dangerous nonetheless.

Dr. Moray's presentation ended with

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a discussion of an attempt to use basic psychophysical research to challenge the myth that basic research found in many popular human factors reference books is useless for system design. To be of any use, basic data must be compiled into look-up tables that can be easily communicated to field engineers. Furthermore, the human factors practitioner must adopt a systems approach similar to that of engineers, if wise design decisions are to be made. Basic research data are too narrowly focused to be useful. Dr. Moray proposed that this myth is partly true, but in an unexpected manner.

To illustrate, Dr. Moray attempted to solve a hypothetical design problem using basic psychophysical data. Dr. Moray imagined that he had been asked by a nuclear power utility to design a temperature gauge that is *always* noticed by the operator when the temperature increases. Dr. Moray assumed that the gauge would probably be a colored bar on a CRT display which functionally resembles a common thermometer. When the sensed temperature increases, the length of the colored bar increases proportionately.

Basic research in just noticeable differences (JNDs) for length would be appropriate in the design of this electronic thermometer. How much must the length increase before a person notices the change 100% of the time? However, the goal of 100% detection is not realistic, any visual stimuli may go unnoticed; the operator may look away, not know where to look, or simply fall asleep. It is fair to ask the client, "What do you mean by *always* detected — 90% of the time, 95%, or 99% of the time?" Supposing that the client said that a 95% detection rate was acceptable, Dr. Moray turned to the classical psychophysical research paradigm to obtain the JNDs for length. Unfortunately, the classical psychophysical paradigm did not account for the false alarm rates adopted by the subjects until the advent of *signal detection theory* several years later. In the classical experiment, if the subject adopted a risky criterion for detecting a stimulus (*I'm not really sure I sense any change in the stimulus, but I'll say "yes" just to be sure*), the resultant JND would be very small. Conversely, if the subject adopts an extremely conservative criterion, the resultant JND would be quite large (*I will never admit that it changed until I see a very large change*). If the smaller JND were incorporated into the design, the operator who adopts a conservative criterion might never detect a change in temperature. Furthermore, classical psychophysical research simply determined the change in stimulus level required to be noticed during 50% of the trials. What is needed for this design is a JND that was detected 95% of the time.

By making a series of assumptions about a range of false alarm rates that were probably adopted in the original experiment, the human factors practitioner *can* make design decisions based on basic research data. Dr. Moray proved that this was possible by incorporating this basic data into the construction of an actual temperature gauge. When corrections were made for the false alarm rates present in the original psychophysical experiments and those adopted by individuals viewing the new display, detection performance could be predicted as a function of the increase in bar length.

This exercise clearly illustrates that assumptions about how basic research data are derived and how they are used in the field must be considered. Management policy, training, and worker attitudes all affect the false alarm rates which may be adopted by the operator. It could be that the danger of taking unwarranted actions in response to this display is not emphasized in training, so operators tend to adopt a risky response bias. If this data were compiled into a dry table form, the system engineer may be misled into making a design decision without taking a systems perspective (i.e., what are the consequences of unwarranted responses?).

At the conclusion of his presentation, Dr. Moray warned human factors practitioners to communicate design recommendations carefully. For example, if a mechanical engineer is asked if a steel beam will support a given load, the answer is always given with a set of implicit assumptions in mind that other engineers understand. It is assumed that the beam will not be exposed to extreme variations in temperature which would cause embrittlement and severely limit its capacity. In effect, basic research data about the strength of steel are communicated within a systems context. Too often human factors practitioners are asked for information out of context; they are required to come up with an exact answer while other human factors influences in the rest of the system are ignored. When making recommendations, the human factors practitioner must make assumptions clear and impress the importance of these assumptions upon the system design team. ●

Suggestions for Further Reading

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Armstrong Laboratory Human Engineering Division Colloquium Series

A Conversation with Neville Moray

Reuben L. Hann

Editor's note: Following is an edited transcript of a conversation with Dr. Neville Moray, University of Illinois, who had just made a presentation as the fifth speaker in the 1993 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL

CSERIAC: One of the interesting areas you have been studying is "trust in automated systems." Could you tell us a bit more about that?

Dr. Moray: There is an extensive literature developing in this area. For example, there's a very interesting book by Zuboff, *In the Age of the Smart Machine*, which talks about the problem of trust when office automation is implemented. In our labs we have worked on simulated process control systems and we are now working on discrete manufacturing systems. We are using a quantitative model of trust between operators and their machines to predict when they will intervene. They will take control of an automated system and run it manually if they think a fault is developing We have some strong models to account for 80 percent of the variance on a trial-by-trial basis, predicting when people will intervene.

CSERIAC: I have noticed that many military systems will only allow the computer to *advise* the human operator, stopping short of full automation.

Dr. Moray: Right. Well, most industrial systems are designed to run under automation. Big process control operations, such as petrochemical plants, may run for several years without shutting down. The role of the operator is what is classically called "supervisory control." You watch and intervene if you have to. The same is increasingly true for discrete manufacturing, which is sometimes difficult for people to accept, although there is some evidence that symbiosis between humans and machines is better than either alone.

CSERIAC: You made some comments during your presentation today about the differences between research for the cockpit versus that for industry. Could you say a bit more about that?

"In the past there was this belief that investment in safety was money lost to profit and productivity. This is almost certainly untrue, because a plant that is running safely is surely in a better condition than one that is down."

Dr. Moray: Yes. I would like to see more effort at places like Wright-Patterson to use the skills developed in designing cockpits for dealing with more general civilian industrial problems. Now, the thing is that in a cockpit, typically you have one or two people, there is a well defined environment—the person does not have to move around, the task is well defined, and the dynamics of the aircraft, on the whole, are understood. In industry, things are not so well defined; people can walk around and the time scale is quite different.

For example, in the case of discrete manufacturing, it's very difficult to tell if something has gone wrong. It may take an hour or two for a particular job to be completed, and if you don't find a component at a particular place in the process, it is difficult to conclude that it's not there yet because something has failed, when an alternative is that the scheduling algorithms believe it's not time yet for it to be there. In other words, it is difficult to deduce from the current state of the plant whether or not it is in the right state to finish the job two days from now.

So, causality is different in process control. In an aircraft, for instance, if you move a control, the physics immediately result in the propagation of the event through the system. But in discrete manufacturing there is no direct force involved. If I send an automated guided vehicle to pick up a part and carry it to some other machine in the factory, it is not being "pushed" there by some pressure; in a sense it is being "pulled" by the need to make this action in order to contribute to the completion of the overall process. So causality in discrete manufacturing processes is quite different—it is difficult to see the variables, it's difficult to keep track of

Continued on page 12

them, they are *asynchronous*—it's a very different world. And, we don't know much yet about how to display this information.

CSERIAC: One of the advantages that the Human Engineering Division has is the ability to conduct more complex studies than are normally possible in the university setting. From your comments, it sounds as though you feel the study of process control would be an appropriate area for us to pursue in the government labs.

Dr. Moray: I certainly do. You have a strong tradition for tackling these kinds of problems. I think it would be relatively easy for the group here to incorporate civilian industrial research in manufacturing and process control into its agenda, and that it would be a very good place to do it.

CSERIAC: It's true, there has been increasing encouragement on the part of the government for the military and industrial worlds to do more cooperative work.

Dr. Moray: Well, I certainly would like to see the kind of expertise you have in the government extended to deal with major industrial problems, because the U.S. is *not* the leader in this area.

CSERIAC: In that regard, I read somewhere you are interested in establishing a better interchange between the U.S. and European human factors communities. You have said that the Europeans are the leaders in many areas. I notice that they appear to have taken the lead in areas such as video display terminal standards for example.

Dr. Moray: Yes. For one thing, there is a much tighter relationship between the human factors community and large-scale industry. There are a lot of cultural differences between Europe and the U.S., and this partly accounts for it. Take the case of standards. I find there is much less fear of centralized government decision-making in Europe than there is here. I think it paralyzes the U.S., because people will not accept the idea that it is possible to have centralized decision for industry. Everywhere else in the world it is done. I think it has many benefits, in fact. In some parts of Europe the unions are beginning to make use of ergonomics to put pressure on for better working conditions. There have been several projects under the ESPIRIT Program which have had very large cooperative efforts, involving three or four universities, several companies, a couple of R&D organizations, and a government lab. They are all working on common problems, such as the nature of the workplace in the year 2000. They are very impressive efforts. I have seen nothing in this country remotely resembling it.

CSERIAC: Something that came out of the discussions today was the observation that ergonomics seems to be getting increased respect from the "hard science" and industrial communities. What are your observations?

Dr. Moray: Well, my experience in the last four or five years has been that several large engineering companies have approached me about the possibility of cooperative projects. I can only think of one occasion during that time when I have had a conversation with someone from a major industry who was completely contemptuous of human factors. Most of the others said they knew it was important, but they didn't know what to do about it, how to use it, or what questions they wanted to ask. However, they did realize that it was very important and might give them a competitive edge commercially.

For industry the main thing, ultimately, is profit. So it is interesting to see that people are becoming more sensitive to safety-at-work issues. In the past there was this belief that investment in safety was money lost to profit and productivity. This is almost certainly untrue, because a plant that is running safely is surely in a better condition than one that is down. If you spend money on safety you will most likely increase productivity, because you will decrease lost work hours, lost labor forces, down time for maintenance—and these all influence productivity. Many formal studies have supported this notion.

CSERIAC: As a final question I like to ask our guests what sort of research they would engage in if they had no funding restrictions. What problem would you tackle if you had virtually unlimited resources at your disposal?

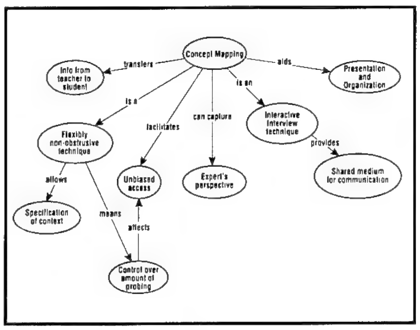
Dr. Moray: I think many of the problems we have not addressed—particularly in the U.S., where the role of human factors has been distorted by being so closely tied to military work—are those involving global problems. These include energy conservation, pollution, population, water shortage, impact of climatological change—the kind of things Ray Nickerson talks about in his new book, *Looking Ahead.* There are problems there which are clearly so serious that the human factors community should be concerned with these as top priority. We could use our skills to help formulate the environment in such a way that people would find it relatively easier to behave in ways which would be good for the planet and society. I would put my money into human factors problems of the 21st century, in terms of pollution, conservation, and planetary and societal issues.

It's not easy, because there is a danger of believing there are human factors *values.* Human factors is no more capable of choosing values and ethics and making decisions than any other science is. It is not at all clear that the solutions human factors would propose are acceptable to other people in other cultures; one cannot export human factors hegemony any more than any other cult. I would like to spend the money on what I call *humane* factors. ●

TAKE A LOOK!

New Concepts in Human Factors Coming this Fall

Tools for Automated Knowledge (TAKE) from the Armstrong Laboratory Human Engineering Division



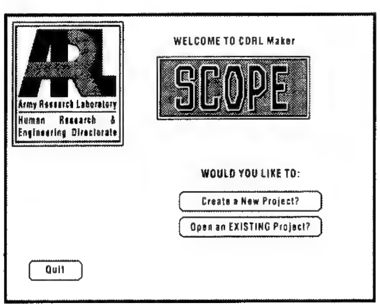
A concept map derived from TAKE

Concept Mapping software for use during system specification and development, user requirement identification, function identification, and task analysis. TAKE is designed to help you map, organize, categorize, and retrieve the volumes of information provided by subject-matter experts and end-users during knowledge elicitation. TAKE runs on a Macintosh Computer System 7.0.

Look for the article in the next issue of Gateway. TAKE will be available this Fall. For further information, contact the CSERIAC Technology Transfer Analyst at (513) 255-4842.

SCOPE IT OUT!

Smart COntract Preparation Environment from the U.S. Army Research Laboratory



SCOPE (Smart COntract Preparation Environment)

Two software programs intended to assist in the preparation of the request for proposal (RFP). Both programs run on a Macintosh Computer System 6.8 or higher.

SPEC Maker - to facilitate the tailoring of two commonly used HFE design standards (MIL-STD-1472D, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities*, and MIL-STD-1474C, *Noise Limits for Military Materiel*) for incorporation in the system specifications.

CDRL Maker - to facilitate the preparation of DD Forms 1423, the Contract Data Requirements List, and the tailoring of the human engineering Data Item Descriptions (DIDs), DD Forms 1664.

Price: $35 each. For further information on SCOPE and its two products, SPEC Maker and CDRL Maker, contact the CSERIAC Technology Transfer Analyst at (513) 255-4842.

Stooped vs. Squat Lifting Techniques

Ed Eveland
Steve Harper
Gavin Hamer
Ken Maynard

Editor's Note: Steve Harper, a Senior Design Engineer for CSERIAC and Adjunct Instructor for the Human Factors Engineering Program at Wright State University, recently taught a course in Industrial Ergonomics. During a collaborative project for this course with St. Elizabeth Medical Center, Dayton, OH, the significance of various lifting techniques and several other factors affecting back injury were examined by two students. The following summarizes their findings.

Most people have been instructed on proper lifting techniques. With the cost of back injury being very high, the need to develop safe lifting practices is obvious. Back pain in the industrial workplace is the most prevalent musculoskeletal disorder reported (Pheasant, 1991). Once a worker sustains a back injury, recurring episodes are likely. It is generally reported that 80% of Americans seek medical attention for a back problem at some time in their lives (Mulry, 1992). In 1992 alone, there were 792,000 back injuries for 24% of all work-related injuries reported in the U.S. (Glisan, 1993). The cost for these injuries was reported in 1989 to include 93 million lost work days, $5 billion in medical expenses, and $12 billion in legal fees and insurance (Berman, 1989).

One of the critical factors related to back injury is the compressional force on the lower spinal column. Another possible factor is Intra-Abdominal Pressure (IAP). The objective of this article is to examine basic lifting tasks and examine these factors within the context of the National Institute for Occupational Safety and Health's (NIOSH) lifting equations.

Traditionally, two lifting techniques or postures are described when discussing the causes of low back pain, the squat and the stooped lift. These postures have been evaluated for their influence on compressional forces measured in the lower back. Since each individual works differently and forces vary depending upon the task, we consider the posture to be ultimately less important than the forces on the L5-S1 area of the spine (see Fig. 1). There is no "ideal lifting technique," although one technique may be better than another for a particular task or individual.

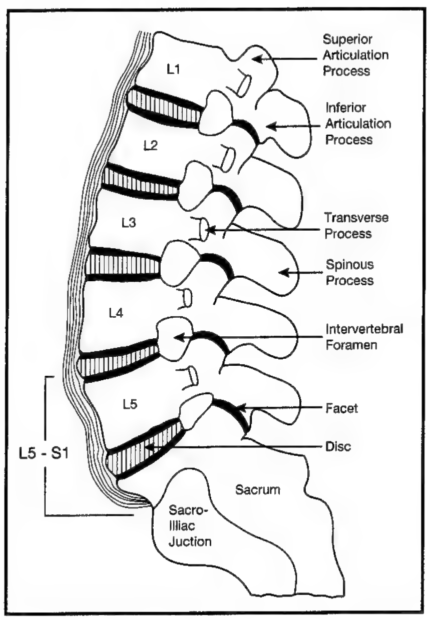


Figure 1. An illustration of the L5 - S1 area of the spine.

The NIOSH Lifting Equation (1981) deals with compressional forces on the spine indirectly. The lifting equation was developed to help evaluate lifting demands and to protect workers from injury. This equation was based on the concept that under ideal conditions, with all factors arranged in the optimal position, a worker can safely lift a weight of 90 pounds. As key factors deviate from the ideal, they receive values that are some fraction of 1. These factors depend upon the horizontal location of the load (HM), vertical location of the load (VM), total vertical distance traveled (DM), and frequency and duration of the lift (FM). The values for these measurements are called multipliers. As a factor deviates from the ideal, its multiplier reduces the allowable weight a worker can safely lift. The weight lifted under these conditions is referred to as the Action Limit (AL) for that lift.

We believe that the horizontal multiplier (HM) portion of the NIOSH Lifting Equation accounts for the majority of the compressional forces acting on the back. The HM varies with lifting posture, indirectly accounting for the actual lifting technique used. The distance of the load from the body and the compressional forces created are the key components of concern. Greater forces are associated with stooped postures due to the mechanics of the back during a lift.

In addition to the AL defined above, NIOSH developed the concept of Maximum Permissible Limit (MPL). The MPL is a quantity three times the AL. NIOSH has established a three-tiered standard for evaluating a lifting task.

Weights up to the AL can be lifted safely by most workers. Weights exceeding the AL, but less than the MPL, can be expected to be safe for most workers, though the probability of an

injury is increased. Tasks performed with weights over the MPL are associated with a high probability of injury, requiring redesign of the task.

In a 1991 revision, new multipliers were added but the concept remains similar. The current equation is

RWL = LC x HM x VM x DM x AM x FM x CM.

RWL is the Recommended Weight Limit. An Asymmetry Multiplier (AM) and Coupling Multiplier (CM) were included in the revision. The revised NIOSH equation was reported in a 1993 edition of *Ergonomics* (Waters, 1993).

When NIOSH developed their criteria for lifting, they used three joints for their model: the knee, the hip, and the shoulder. They calculated compressional forces on the back from the angles between these joints. There has been some question of whether this is adequate. Measuring from the hip to shoulder does not completely describe the position of the lower spine. Spinal curvature can differ a nearly infinite amount for the same measurement between these two points. A model proposed by Jager and Luttman (1989) uses an 18-joint human model which has one rotational point for each of the five lumbar vertebrae. This model represents a more complex method for determining back posture.

Additional analysis can become very complicated. There are six fundamental equations of equilibrium (3 forces, 3 moments); however, the high number of muscles acting on the spine makes static solutions difficult at best. Trying to use linear approximation on complex models like Jager and Luttman's would result in burdensome analyses. This was not the NIOSH goal. Inclusion of too much complexity could end in guidance that is difficult to follow. Compliance in the work force would be less than with something simple. If people don't use guidelines, the guidelines become useless.

While examining the biomechanics of this problem, we found many instances of speculation on the role of intra-abdominal pressure (IAP) during lifting tasks. It seems the majority of evidence favors a supporting role where IAP might stabilize the spine. IAP is always involved but the part it plays is not a critical one. Changes in compressional forces are the deciding factor and these changes are generally independent of intra-abdominal pressure.

It is evident that there are many factors to consider when suggesting ways to lift "correctly." The bottom line is that the 1981 NIOSH guidelines have been successful in reducing injuries. That was the goal. This is confirmed in a review found in a 1985 issue of the *Journal of Occupational Health & Safety* (Liles & Mahajan, 1985). Data shown there indicate that lifting within the Action Limit results in fewer injuries.

It is our conclusion that NIOSH has created guidelines that include ways of addressing critical factors in lifting tasks. They do this in a way that may intentionally be less detailed in a compromise intended to encourage widespread use of their guidelines in the workplace. ●

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CSERIAC Search & Summary
Electronic Food Kiosks

Ken Klauer

Recently CSERIAC was able to aid in the design of a new concept in food service—electronic ordering. CSERIAC was tasked by the Human Factors Group at AT&T to perform a Search & Summary of the human factors issues in the design of electronic public kiosks. These kiosks might remind one of automated teller machines now found on virtually every block, only instead of handling financial transactions, they will be used to place orders at a popular chain of fast-food restaurants as shown in Figure 1. While these kiosks probably won't be found on every corner, they will provide customers with an alternative to long order lines. For example, busy mall shoppers will be able to order ahead via an electronic food kiosk located in the vicinity of the restaurant. These kiosks will also be used inside the restaurant to reduce the demands on restaurant staff during peak hours.

With CSERIAC's assistance, AT&T identified two general areas of human factors concerns in relation to kiosks. The first concerned the construction of kiosks; what features would attract the customer and prompt him or her to interact with the kiosk? What are the ideal physical dimensions of such a kiosk to facilitate easy access by users of all sizes and physical abilities? Does any literature exist concerning the security and durability of similar public devices? The second major concern was the general usability of the kiosk order interface; what type of interface would facilitate efficient interactions by a diverse group of users? The population of potential users will vary widely in their language skills, experience, and acceptance of computerized devices. In this particular project, a CSERIAC human factors analyst also suggested that the speed of user feedback may have a significant impact on user acceptance of this new food ordering system.

To initiate this task, CSERIAC worked with AT&T to write a brief but concise statement describing these specific areas of concern. This exercise helped both AT&T and CSERIAC fully understand the specific design problems and identify key words and possible search strategies. From this task statement and key word list, a CSERIAC *Search & Summary* was generated which provided AT&T with over 160 references to articles addressing human factors issues in kiosk design culled from over 400 initial articles across 600 databases. This material was received by AT&T in the form of a bound document containing the key words and search strategy used, as well as the resulting references and abstracts. Each Search & Summary also contains an additional section that quickly refers the reader to entries that appear to be especially informative.

Because CSERIAC analysts perform hundreds of searches annually, we are

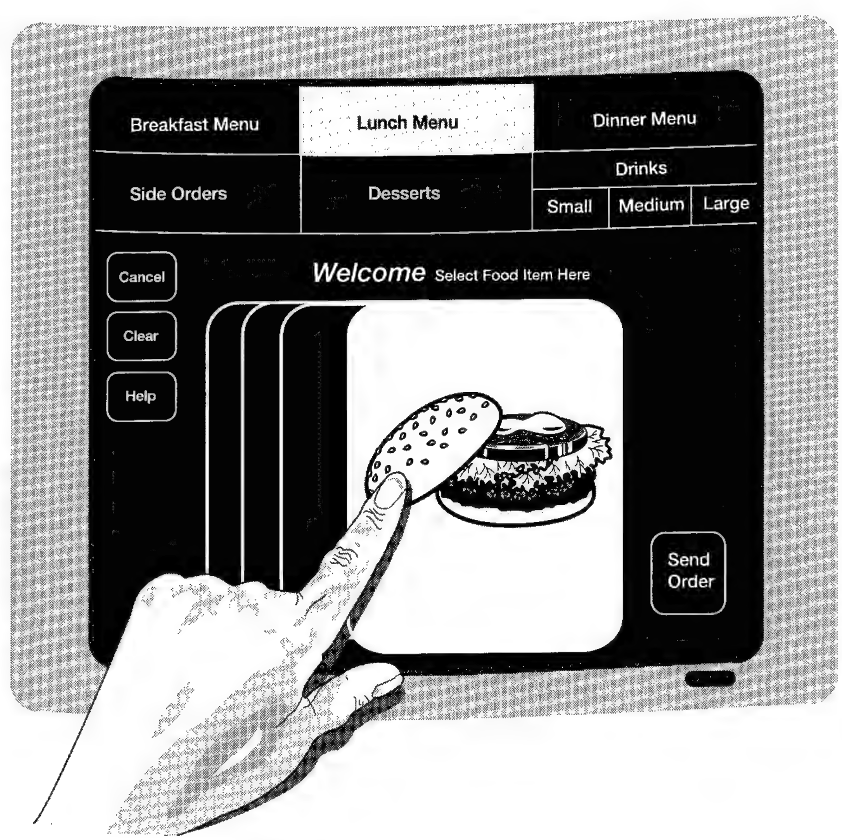


Figure 1. Placing orders at fast food restaurants will eventually become automated with electronic food kiosks similar to that depicted here. Illustration by Ronald T. Acklin.

able to offer our clients the benefits of experience. An early design hypothesis was that the final form of the AT&T system would utilize a touch screen interface; therefore, a CSERIAC analyst was able to review a past Search & Summary on touch screens to find databases that were particularly fruitful and to identify search terms associated with each database that would produce a large number of "hits." Other similar technologies were identified that provide many clues as to the design of highly usable food kiosks. CSERIAC analysts considered any type of public device employed by "occasional users," such as beverage and ticket vending machines, automated teller machines, automated information kiosks, and multimedia displays used in museums and trade shows.

While AT&T could have chosen to send project members to a local library to find these references, they probably could not have performed a search as complete as CSERIAC is able to offer. It would have taken many hours just to learn the various idiosyncracies of each database to ensure that all relevant information was found. Often, pertinent literature is not simply found under *interfaces, human factors of....* The human factors analysts at CSERIAC are highly adept at finding the information our clients need quickly; a CSERIAC Search & Summary can be generated in approximately 2 to 3 weeks. In addition, at only $975.00, CSERIAC is able to offer this comprehensive service at a cost far below what many of our clients would invest to perform a comparable search in house.

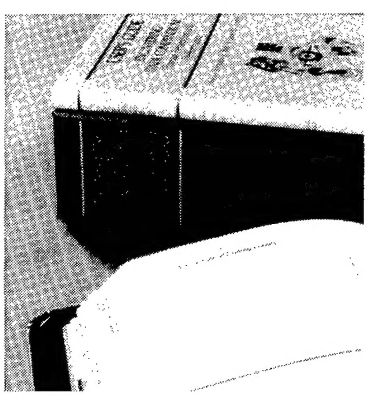
A CSERIAC Search & Summary is a resource that can be used again and again by many of our clients. It is likely that many of the projects the Human Factors Group at AT&T will undertake in the future will involve interfaces that must be used by a similar population; therefore, a single Search & Summary can be used many times over. Mr. Ali Vassigh, project leader at AT&T's Human Factors Group, feels that a CSERIAC Search & Summary saved his project team valuable time. Mr. Vassigh also commented that the CSERIAC Search & Summary "gave us (AT&T) a comfortable feeling about the prototype...a feeling that we had covered all the bases."

A CSERIAC Search & Summary can be a valuable asset to any project. Search & Summaries have been published on a number of diverse topics, ranging from underwater operations to space exploration.

For further information on a CSERIAC Search & Summary, feel free to contact a CSERIAC human factors analyst at (513) 255-4842, DSN 785-4842, or email: CSERIAC@falcon.aamrl.wpafb.af.mil. ●

Ken Klauer is a Human Factors Analyst for CSERIAC.

AN ERGONOMIC APPROACH TO ERGONOMICS DATA



Engineering Data Compendium: Human Perception and Performance edited by Kenneth R. Boff and Janet E. Lincoln (1988)

Engineering Data Compendium: Human Perception and Performance is a landmark human engineering reference for system designers who need an easily accessible and reliable source of human performance data. Editors Kenneth R. Boff and Janet E. Lincoln make understanding, interpreting, and applying technical information easy through their innovative format. This four volume, 2758 page set features nearly 2000 figures, tables, and illustrations in several well-structured approaches for accessing information. Brief encyclopedia-type entries present information about basic human performance data, human perceptual phenomena, models and quantitative laws, and principles and nonquantitative laws. Section introductions provide an overview of topical areas. Background information and tutorials help users understand and evaluate the material.

For further information on the Engineering Data Compendium, contact CSERIAC at (513) 225-4842.

Review: Color in Electronic Displays

Charles J. C. Lloyd

Editor's note: The following is a reprint of a review of the book, Color in Electronic Displays. *This review was prepared by Charles J. C. Lloyd and first appeared in* Color Research and Application, 19*, 1994. Copyright © 1994 John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.* Color in Electronic Displays *is available through the CSERIAC Program Office for $45.*

I am pleased to have been asked to review the book *Color in Electronic Displays* (335 pages) edited by Heino Widdel and David L. Post (1992), and published by Plenum Press. After examining this book I can recommend the book as a valuable addition to the library of persons who are involved in the research, development, evaluation, or specification of color electronic display systems.

As a human factors scientist in the avionics industry, I frequently work with color avionics display systems. In this capacity I have found it necessary to draw on a wide range of journal papers, books, technical reports, standards, specifications, and seminar lecture notes spanning several disciplines. Though I have spent years assembling my own collection of references on this topic, I still regularly come across important references I wish I had found while working on projects past. The authors and editors of *Color in Electronic Displays* have collected and integrated the bulk of this literature and published the results in a single volume. The reader is thus saved the significant amount of time required to identify, collect, and review this large body of widely dispersed literature.

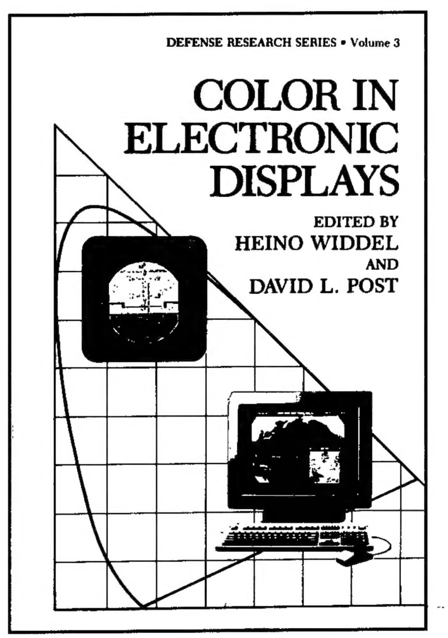
Like the field of color science, *Color in Electronic Displays* has an international flavor with contributions from leading authors in Canada, France, Germany, Italy, the Netherlands, the United Kingdom, and the United States. The book was produced by the Research Study Group 13 on "Human Engineering Evaluation on the Use of Colour in Electronic Displays," which is a part of the NATO Defense Research Group. The book is organized into four sections with each section summarized below.

Section One (two chapters) provides the reader with an introduction to color vision, perception, and measurement with an appropriate emphasis on the differences between perception and the physical stimulus. Important perceptual artifacts as well as the incidence and types of color deficiencies occurring in the population are summarized along with their design consequences. The second chapter in this section presents an overview of modern colorimetry including descriptions of the most important color spaces used in the displays industry.

Section Two (three chapters) presents descriptions of the theoretical and applied color research methodologies that are of most interest to the display systems designer. The first chapter describes the psychophysical, physiological, and behavioral methods used by scientists to characterize the nature of human color vision. The second chapter describes a number of applied research methods that are used to characterize visual performance in the context of specific display technologies. The final chapter in this section discusses a number of important operational and environmental factors that moderate the observer's perception of color.

Section Three (two chapters) concentrates on the practical uses of color on electronic displays. Effective uses of color coding are described, which are generally supported by improvements in operator/system performance. Also described are a number of specific applications where color coding has been used successfully. The second chapter of this section reviews common color coding conventions as well as both military and commercial standards regulating the use of color.

The first three chapters of Section Four (four chapters) provide the reader with overviews of the major color display technologies currently in use including CRT, flat-panel, and projection display systems. Each of these chapters presents historical



Color in Electronic Displays *edited by Heino Widdel and David L. Post (1992). Published by Plenum Press.*

summaries, principles of operation, descriptions of typical applications, and some of the important advantages and disadvantages of each technology. The last chapter of Section Four discusses the equipment and measurement methodologies used for characterizing and calibrating self-luminous color displays.

I have found *Color in Electronic Displays* to be valuable both as a tutorial and as a comprehensive source of references. Moreover, the text is an excellent introduction to the standards and current practices employed in the electronic displays industry. I highly recommend the text to persons working on the research, development, evaluation, or specification of color electronic displays. ●

Charles J.C. Lloyd, Ph.D., is a Human Factors Specialist with the Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY.

Proceedings from the Working Group on:

Whole-Body, Three-Dimensional Electronic Imaging of the Human Body

Edited by

Michael W. Vannier ■ Ronald E. Yates ■ Jennifer J. Whitestone

Electronic imaging of the surface of the human body has been pursued and developed by a number of disciplines including radiology, forensics, surgery, engineering, medical education, and anthropometry. The applications range from reconstructive surgery to computer-aided design (CAD) of protective equipment. Although these areas appear unrelated, they have a great deal of commonality. All the organizations working in this area are faced with the challenges of collecting, reducing, and formatting the data in an efficient and standard manner; storing this data in a computerized database to make it readily accessible; and developing software applications that can visualize, manipulate, and analyze the data.

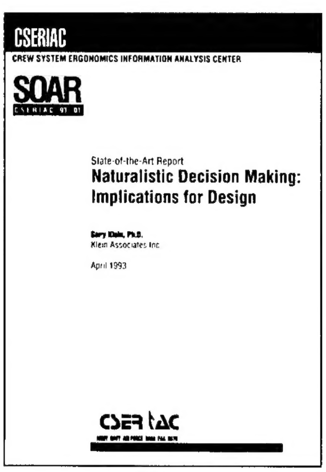
This working group was sponsored by the Human Engineering Division of the Armstrong Laboratory (USAF); the Mallinckrodt Institute of Radiology; the Washington University School of Medicine; and the Lister-Hill National Center for Biomedical Communication, National Library of Medicine, in an effort to encourage effective use of the resources of all the various groups and disciplines involved in electronic imaging of the human body surface by providing a forum for discussing progress and challenges with these types of data.

Five main areas of interest are reported on:

- **Development of Scanning Systems**
- **Data Storage and Interchange Format Standards**
- **Calibration, Validation, and Evaluation of Scanning Systems**
- **Data Analysis, Image Processing and Display**
- **Physically Based Modeling of Deformable Objects**

The proceedings are 200 pages and include 82 figures. The cost is $35. To order, contact the CSERIAC Program Office at (513) 255-4842.

■ STATE-OF-THE-ART IN HUMAN FACTORS ■



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Three-Dimensional Displays: Perception, Implementation, Applications (Wickens, Todd, & Seidler, 1989)

Naturalistic Decision Making: Implications for Design (Klein, 1993)

Price: $35 each. To order these SOARs or other CSERIAC Products, contact the CSERIAC Program Office at (513) 255-4842 or DSN 785-4842.

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CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

- technical advice and assistance;
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- written reviews and analyses in the form of state-of-the-art reports and technology assessments;
- reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

- organizes and conducts workshops, conferences, symposia, and short courses;
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